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INDIVIDUAL DIFFERENCES AND FAMILY RESEMBLANCES IN ANIMAL BEHAVIOR

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IN experimental work on animal behavior, but little attention has been paid to individual differences, and practically none to family resemblances.[1] In studying the inheritance of conduct in man, experimental methods can not be used. Students of eugenics depend on observations difficult to verify. In the work here described an attempt has been made to apply the methods of genetics to the study of conduct. Such work was begun by Professor J. McKeen Cattell some fifteen years ago, but the results obtained by him and his students were not published, and the problem has been given to me.[2]

The plan of the experiment is to measure individual differences in behavior, to determine the extent to which the animal which departs from the average in one direction will depart in others, to measure the resemblances in families and in lines of descent, and to determine the degree to which kinds of conduct can be established in family lines by selection. It is evident that such a problem can be solved only by many years of work and with the facilities of a research institution. In the present paper there are described the individual differences and family resemblances of 90 mice, as determined by the time required to find their way through a maze. The same mice have been tested in other ways, and further experiments are now in progress with the F^5 and F^6 generations.

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[1] Basset has recently published an article on "Habit Formation in a Strain of White Rats with Less than Normal Brain Weight." *Behavior Monograph Series,* No. 9, 1914. Macdowell in *Science* for November, 12, 1915, gives a brief abstract of work on "Parental Alcoholism and Mental Ability. A Comparative Study of Habit Formation in the White Rat."

[2] The greater part of the work presented in this paper was done at Columbia University, the results being used for a master's thesis.

A maze, designed by Professor Cattell, was used, the plan of which is shown in Fig. 1. The animal has in the first compartment the alternative between two gates, one of which can be pushed open while the other is locked, and then it has the same alternative in the second compartment. When it takes the correct way in both compartments, it finds itself in the food compartment. The path that the animal must follow can be altered by changing the gates which are locked. "Unit construction" is used in the dimensions, which are adjusted to the size of the animal, and in the fact that any desired number of standard units can be added.

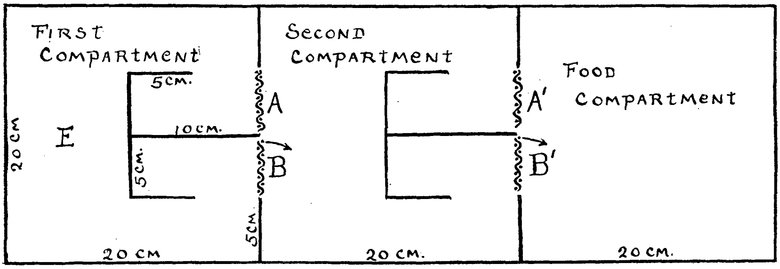

FIG. 1. Diagram of Maze. *A* and *A'* = closed wire gates; *B* and *B'* = open wire gates; *E* = entrance from above.

Preliminary tests were made with albino rats, but these were given up for mice, which are more active and more easily handled. The mice were given one trial each day, and were tested at as nearly the same time as possible. Light was found to play but a minor rôle in the tests, daylight and artificial light serving equally well. At the outset the age of the mice when first tested was not always known, but later when the various litters were obtained the young mice were tested at or about four weeks old.

The mice were rewarded for a successful trial by a mixed diet of milk, bread, oatmeal and sometimes meat. They always had a little dry bread in their cages. Besides satisfying their hunger, the mice had the additional reward of a place for exercise and the companionship of the mice that had just been tested. The order of the tests was varied day by day. In case the way through the maze was not found in 360 sec. the animal was removed and tested again the following day. 360 sec. is thus the maximum record for a single trial.

Seventeen trials were made with each individual. This was a desirable number for two reasons: first, because this number was sufficient for the average mouse to learn the maze, and secondly, because the seventeen trials could be divided into three somewhat homogeneous groups. The first two trials are largely affected by chance, so, although given here for completeness, they are not averaged in the final ratings for each individual. The second group of five trials represents the period of more rapid learning, the third group of ten trials the results when the learning is slow or completed. In this paper the averages of the last fifteen trials are used as the index of performance. For some purposes the last ten or the last five trials might be preferable. The rate of learning as determined by the relation between the first and last groups may also prove to be of value.

In addition to the time, the number of errors, *i. e.*, the number of cases in which the mouse tried to go through the locked gate, is given in the tables, as this is a measure of the activity of the animal. With only a few exceptions, however, the error and time curves correspond. Consideration of the correlation between error and time, and between performances at the beginning and the close of the trials is postponed until data can be given for a larger number of individuals and the records for other kinds of behavior.

In Tables I to V are given the complete records of the 90 mice tested, grouped in families as described below. The average time is 44 sec. per trial for the last fifteen trials. The distribution of the individuals is shown in Fig. 2. In 41 cases the time was under 20 sec., in 19 cases between 20 and 40 sec., in the remaining 30 cases between 40 and 200 sec. None of the mice failed to learn the maze.

When the experiment started, several colored mice—chocolate, agouti, gray, black and yellow—were tested,

TABLE I

Complete Time and Error Records for the Yellow Family

No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average	No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average
20Y ♀	360	228	58	115	1.6	38Y ♂	360	277	98	157	3.6
21W ♂	247	41	11	21	.2	39Y ♂	360	143	25	64	2.3
22W ♂	234	28	14	19	.4	40Y ♂	360	47	9	21	.8
23AG ♂	280	43	6	19	.5	41Y ♀	210	20	8	12	.5
24AG ♂	182	47	8	21	.9	57Y ♂	360	171	109	130	3.7
25AGW ♀	177	136	26	63	1.7	58Y ♂	357	130	51	77	2.4
26Y ♂	360	206	172	183	3.7	59Y ♂	360	275	98	156	3.3
27Y ♀	201	10	14	13	.5						

In the first column is given the catalogue number, color and sex of the animals. In the second are the time averages (in seconds) for the first two trials; in the third, for the next five trials; in the fourth, the last ten trials, and in the fifth column the average of the two preceding columns. The error average for the last 15 trials is given in the last row of figures. This order is followed in all the subsequent tables.

One day's record has been omitted for mice Nos. 27, 28, 29 and 31 because the poor records for that day were obviously due to a constant error, on account of traveling, etc. These are the only cases where such a condition has occurred.

TABLE II

Complete Records for the White Family

No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average	No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average
12W ♂	360	91	56	67	1.9	103W ♂	108	5	10	8	.5
13W ♀	100	159	37	91	1.4	104W ♂	174	12	13	12	1.0
15W ♀	316	26	17	21	.4	105W ♀	99	12	11	11	.8
48W ♂	156	16	7	10	.5	106W ♀	284	22	12	15	.9
49W ♀	185	75	25	42	1.9	109W ♂	101	69	8	28	.9
50W ♀	246	25	18	20	.7	110W ♂	93	11	7	8	.4
51W ♀	56	13	7	9	.5	111W ♂	67	13	12	12	1.0
52W ♀	169	12	10	11	.9	112W ♂	151	33	8	16	.9
53W ♀	196	77	34	48	1.7	113W ♂	88	11	7	8	.7
65W ♀	285	87	8	35	.9	114W ♀	75	13	5	8	.4
66W ♂	360	306	17	113	1.2	115W ♀	70	13	11	12	1.0
67W ♀	360	173	25	75	1.7	116W ♂	183	13	8	10	.7
76W ♀	222	58	17	31	.9	117W ♂	318	11	4	7	.5
77W ♂	317	162	20	68	1.0	118W ♂	81	14	10	12	1.0
78W ♂	360	186	91	122	2.9	119W ♂	115	40	9	20	1.1
71W ♂	149	121	18	53	.9	120W ♀	118	19	7	11	.5
72W ♀	360	304	30	121	1.7	121W ♀	64	17	9	12	.7
74W ♀	89	29	21	24	1.2	122W ♂	76	84	7	33	.7
86W ♀	84	19	13	15	1.2	123W ♀	66	39	29	32	2.2
87W ♀	58	16	14	15	1.2	124W ♀	25	23	10	14	.9
88W ♀ ♀	86	14	7	9	.8	125W ♂	189	15	7	9	.5
89W ♂	110	16	10	12	.9	126W ♂	90	19	9	12	1.0
91W	252	47	33	38	1.6	127W ♀	72	22	11	15	.9

TABLE III

COMPLETE RECORDS OF A FAMILY CONSISTING MOSTLY OF YELLOW INDIVIDUALS

No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average	No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average
32Y♂	225	109	71	83	1.7	61Ch♂	360	202	30	87	1.0
33Y♂	154	186	42	90	.5	62YW♂	312	90	18	42	1.5
34Y♂	186	88	39	56	1.0	63YW♀	243	130	38	69	1.2
36Y♂	354	55	28	37	.9	64Y♀	360	182	113	136	2.3
37Y♀	137	20	16	17	1.2	68YW♀	112	71	65	67	2.0
54W♀	360	36	34	35	.7	69Y♂	177	41	9	19	.7
55Y♂	360	242	103	150	3.5	70Y♀	234	223	75	124	2.3
56Y♀	360	130	103	112	2.0						

TABLE IV

COMPLETE RECORDS OF A SMALL FAMILY SHOWING GOOD RECORDS

No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average	No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average
29W♀	229	9	8	8	1.3	45W♀	142	13	5	8	.5
30Gr♂	58	43	33	36	1.0	46Gr♂	141	9	4	6	.5
44W♀	297	16	7	10	.5	47Bl♂	150	34	29	31	1.0

TABLE V

COMPLETE RECORDS OF THE UNRELATED INDIVIDUALS

No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average	No.	First 2 Trials	Next 5 Trials	Last 10 Trials	Last 15 Trials	Error Average
1Ch♂	212	48	11	23	1.0	5W♀	74	22	8	12	.6
2Y♀	285	213	103	140	5.1	28W♂	291	38	5	17	1.0
3Y♀	316	55	63	61	3.3	31Gr♀	130	78	15	38	1.0
4W♂	77	18	14	16	.7	85W♂	131	14	9	11	.8

besides a large number of albinos, and among the yellow mice several made poor records. These mice were mated, and they and their offspring compose a group of 27 individuals, whose average time and error record is considerably in excess of the normal for the entire population.[3]

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[3] This group of 27 mice was composed (see Tables I, III and V) of Nos. 20 and 26, and their seven offspring; No. 27, the sister of No. 26; a litter of five mice, Nos. 32, 33, 34, 36 and 37 and their ten offspring, and finally two unrelated yellow mice, Nos. 2 and 3, that were used at the beginning of the experiment. The 63 remaining mice of the white group bring the total to 90.

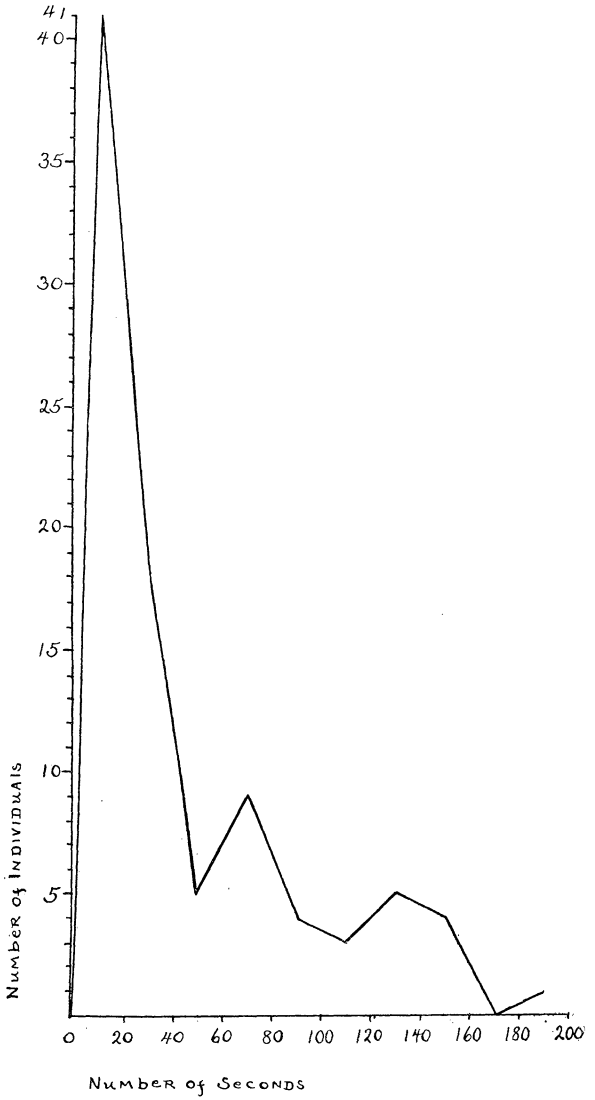

FIG. 2. Total distribution curve for 90 individuals for the last 15 trials.

The yellow group gave an average time of 83 ± 7.0 sec., and an average of 2.0 errors for the last 15 trials. The other mice gave an average time of 27.5 ± 2.0 sec. and .9 error per trial. The yellow mice were thus found to take, on the average, at least three times as much time and to make twice as many errors as did the white mice. In Fig. 3, the distribution curves of both groups are given, the yellow in a broken and the white in a solid line. The curve for the miscellaneous group is skewed, most of the individuals falling between 0 and 20 sec. The curve for the yellow family is nearly flat, there being about the same number of individuals in each time group.

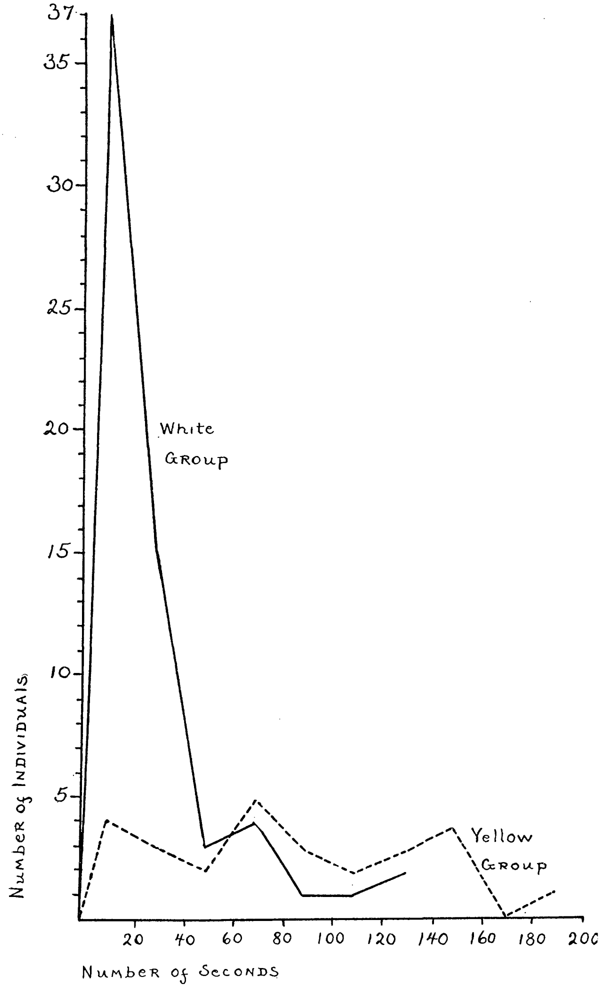

FIG. 3. Distribution curves of yellow and white groups for the last 15 trials.

Fig. 4 gives two average practise curves, one for the group of 63 white and colored mice, and the other for the group of 27 mice that are mostly yellow. The records of

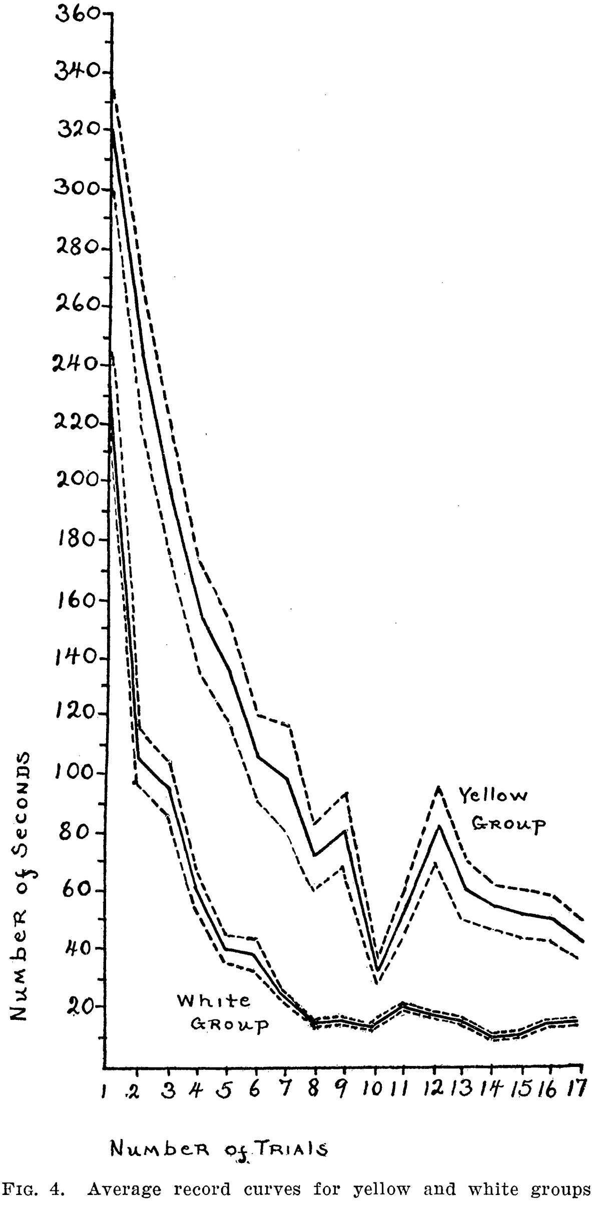

FIG. 4. Average record curves for yellow and white groups.

all the individuals for each successive trial were averaged, and the probable error calculated for each point on the curve. In accordance with a plan proposed by Professor Cattell, the limits of the probable error are shown by broken lines. The chances are even that with a greatly increased number of cases the time would have remained within these limits, and a nearly smooth curve can be drawn within them. A notable exception is the tenth trial with the yellow mice. At this point there is an unusually

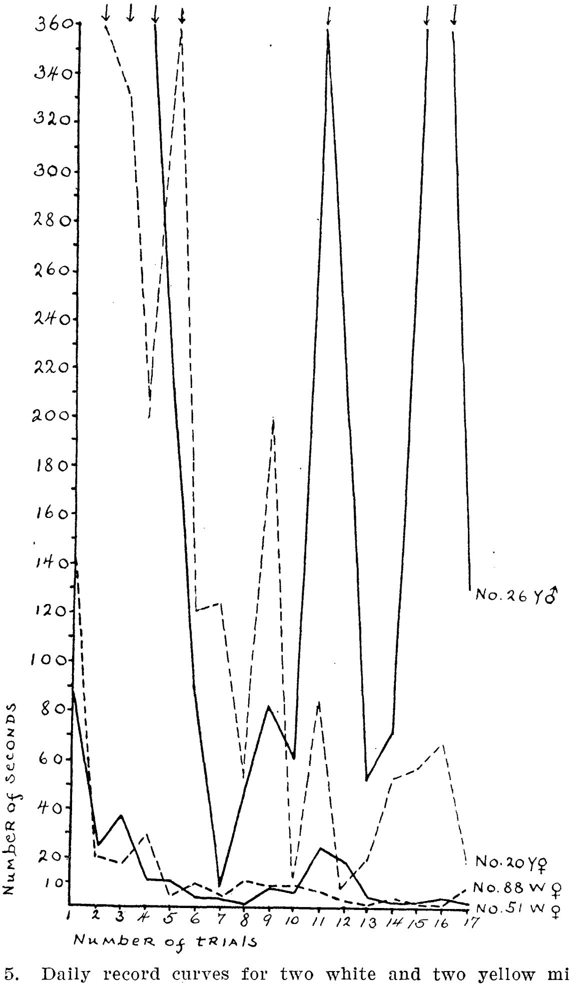

FIG. 5. Daily record curves for two white and two yellow mice.

large number of low records, more than the law of probability would warrant.

In Fig. 5 are given sample practise curves, showing the daily records for two white mice, Nos. 51 and 88, that learned the maze quickly, and for two yellow mice, Nos. 20 and 26, that were slow to learn. The arrows at the highest points indicate that the mouse did not pass through the maze. Thus No. 26 only got through on the fifth trial and failed in the eleventh, fifteenth and sixteenth trials.

The mean variation for the entire group of 90 mice was found to be 35.6. This means that any mouse picked at random from the mixed group would be likely to vary from the average by 35.6 seconds. In order to find whether mice of the same litter varied less than unrelated individuals, the mean variations for each of the 18 families was calculated, and these when weighted for size of family were found to be 20.2. The resemblance in behavior between mice belonging to the same litter was consequently nearly twice as great as between unrelated individuals. This corresponds to a coefficient of correlation in the neighborhood of 0.5 for brothers, as found by Pearson, Thorndike and others.

TABLE VI

AVERAGES FOR SEX DIFFERENCES

No.	Color	Sex	Average Last 15 Trials	Probable Error	Average Number of Errors
32	White, etc.	♂	27.69 Sec.	± 2.9	.9 per trial
31	White, etc.	♀	27.35 Sec.	± 2.9	1.0 "
15	Yellow, etc.	♂	90.0 Sec.	± 9.6	2.0 "
12	Yellow, etc.	♀	75.0 Sec.	±10.3	2.1 "

In Table VI, the males and females are grouped separately, and their average times and errors are given. In both groups of (mainly) white individuals, with 32 males and 31 females, and in the group of (mainly) yellow mice, with 15 males and 12 females, the times for the females are on the average slightly shorter, but the differences fall within the limits of the probable error and indicate that there are no sex differences in this kind of behavior.

We may now take up in more detail the family histories. Fig. 6 gives a graphic representation of matings, from which there were selected two mice, No. 20 Y♀ and No. 26 Y♂, which made unusually poor records, 115 and 183, respectively, though the other mice in the same litters had good records. The parentage of Nos. 20 and 26 was unknown; they were mated and gave two litters, each composed of three males and one female. Three mice in these two litters gave unusually slow records and made considerably more errors than normal. Two other mice gave poor records; two gave good records, while one died before it was tested. It is unfortunate that both females in these litters died before further offspring could be obtained. Table I gives the complete record of both time and error averages for these mice. It is a question whether or not the selection of parents having poor records tended to produce more than the normal number of offspring slow to learn. Further investigation can alone afford an answer.

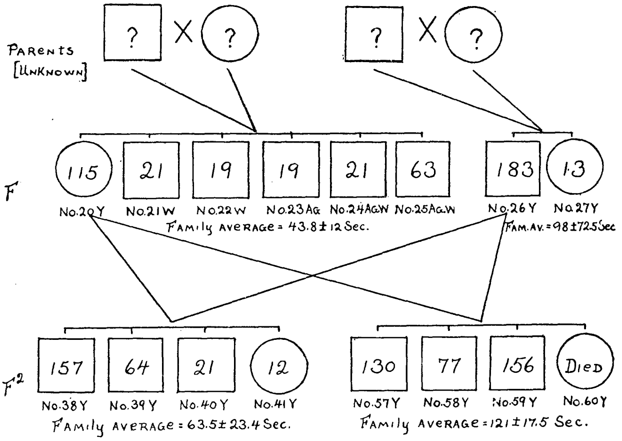

FIG. 6. Descent of yellow family. Squares denote males and circles females. The numbers within the circles and squares represent the average time taken for the last fifteen trials. The manner in which the yellow mice in these experiments have given an unusually large number of yellow offspring has been made the subject of another investigation from a mendelian standpoint.

The mice whose records are given in Table II are graphically represented in Figs. 7 and 8. They have been carried down through the sixth generation, and are still being tested. As neither of the mice of the F^4 generation mated with No. 91, the only individual of the F^5 generation, No. 91 was mated successively with four unrelated

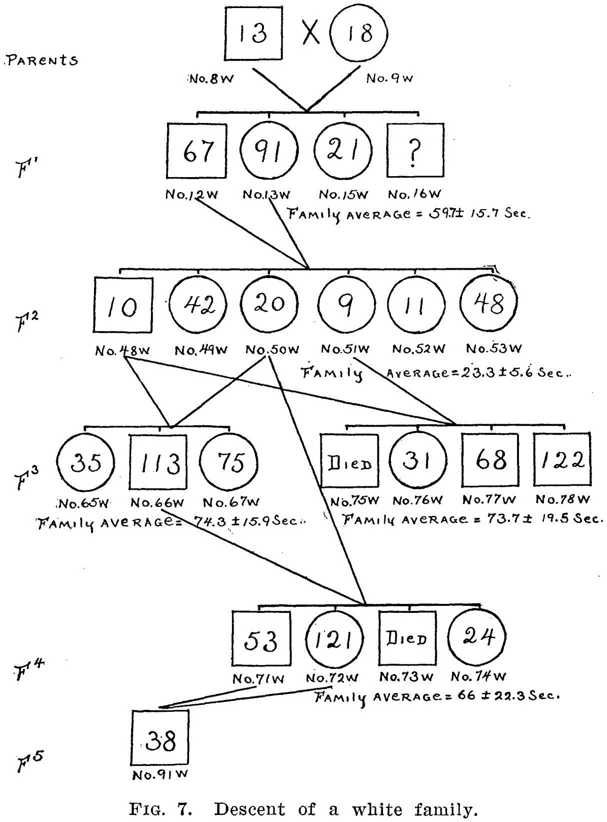

FIG. 7. Descent of a white family.

white females, Nos. 86, 87, 88 and 89. These females had been previously tested and found to give exceptionally good records as indicated in Table II. Twenty-three offspring resulted from these matings. Their records are remarkably uniform and the family averages are the lowest so far obtained. The records of these families are graphically represented in Fig. 8, and here only the continuation of the white family is given showing the F^5 and F^6 generations separately for each individual family. It is hoped that future offspring may be obtained to continue this strain. The times for the fifteen trials do not always correspond with the times for the last ten trials.

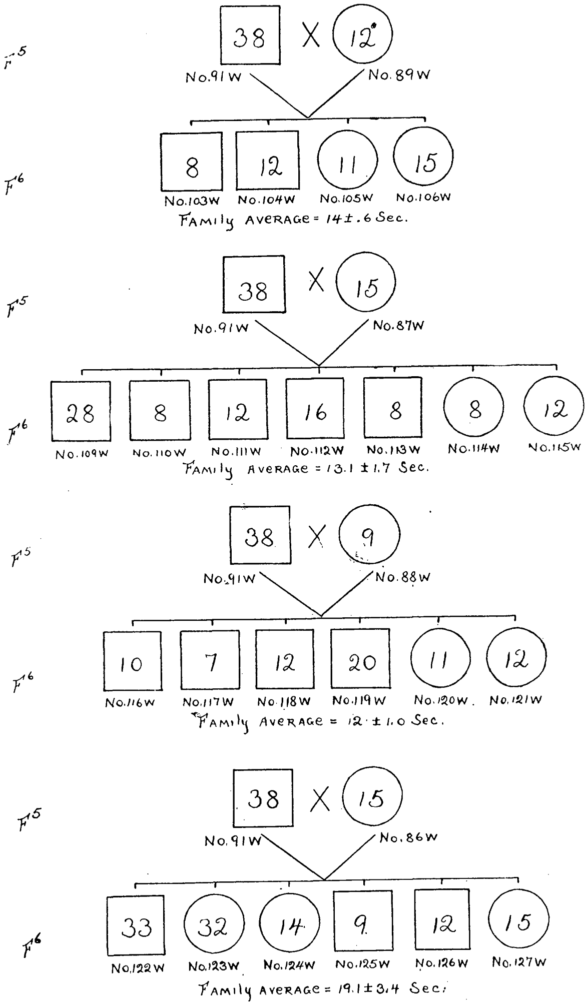

FIG. 8. Continuation of white family. No. 91 mated with four females.

Thus No. 66 has for the fifteen trials an average time of 113 sec., but in the last ten trials reduced the time to 17 sec. The capacity of the mice can only be finally determined after the same individual has been tested by different methods.

Another family, mostly yellow, was derived from a yellow female and an unknown male, probably white. The F^1 from this mating gave a litter of six, Nos. 32 to 37 inclusive. The records of 5 of these (one died) are given in Table III and are graphically represented in Fig. 9. The only female of the litter (No. 37) mated but once, and it is not known with which brother. She bore in the F^2, two females and a male (Nos. 54, 55, 56). Both females of this generation were crossed with their brother and two litters resulted. No. 55 × 56 gave Nos. 68, 69 and 70 in the F^3, and No. 55 × 54 gave Nos. 61 to 64 inclusive. From a survey of the complete records of these mice, it is seen that although the F^2 and F^3 generations came from the female, No. 37 (which made the exceptionally low record of 17), still two of her young in the F^2 made poor records, and Nos. 61, 64 and 70 in the following generation did the same.

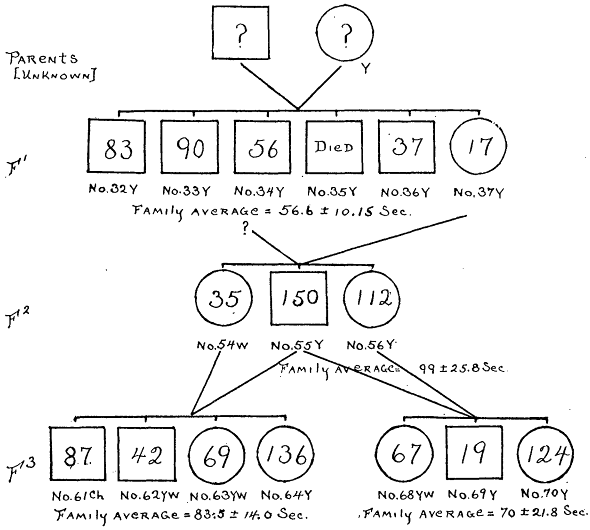

FIG. 9. Descent of a family of mice consisting mostly of yellow individuals.

The records of a family of white and colored mice are given in Table IV and Fig. 10. The two parents and the four offspring all have good records. It is to be regretted that no further litters were obtained from this family.

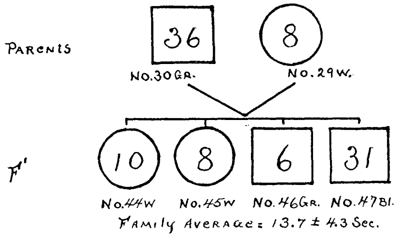

FIG. 10. Descent of a small family of mice showing good records.

In Table V are given the total records for the isolated cases, which complete all the individuals tested. Here again the relative inferiority of the yellow mice may be noted.

SUMMARY

1. Albino and colored mice can be used to advantage for laboratory work on animal behavior.
2. The type of maze used seems well adapted for this kind of work.
3. There is a marked difference in individual behavior.
4. There appears to be a resemblance among individuals of the same litter.
5. There appears to be a considerable difference among different strains.
6. The sex differences, if any, are very slight.